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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

Symposium on " Nuclear fuel cycles "

The Institute is arranging a Symposium in London on " Nuclear fuel cycles " on January 22 and 23, 1959.

The program is as follows :—

Session 1 (*a*) " Long term reactivity changes "
(*b*) " Theory of once-through fuel cycles"
(*c*) " Perturbations due to fuel cycles."

Session 2 " Optimization of fuel cycles for nuclear power stations."

Session 3 " Fuel cycle operational problems."

The papers which have been invited will cater mainly for persons working in the field, and will deal with the applied physics aspects of the fuel cycles which form the basis of the immediate nuclear power program. Abstracts (but not pre-prints) of the papers to be read or presented at the Symposium will be available early in January.

Application forms for tickets to attend the Symposium are obtainable from the Secretary of the Institute and should be returned as soon as possible.

Half Yearly List of Meetings

The list of meetings for the first half of the coming session will not be issued as a booklet, as has been done in the past few years. Instead, a complete list of meetings up to the end of January, 1959, will be published in the September *Bulletin*. Individual notices will be sent as usual to Branch and Group members.

The Statistician and Sample Testing*

By A. N. JAMES, B.Sc., A.I.S., F.S.S.

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INTRODUCTION

It is generally conceded that tests have to be made on batches of materials or on manufactured goods themselves at some stage or stages of a production process. These tests are made for a variety of reasons: to prevent poor materials from being fed into a production line; to avoid putting second quality goods on the market; to ensure that a process is running satisfactorily; to provide data for technical or administrative action.

The purposes to which the data from these tests are put may be divided roughly into two categories:

(*a*) Tests whose sole purpose is to provide information.

(*b*) Tests, the results of which are used to make definite decisions.

Under the first heading are all those tests which are made in order to give a picture of the behaviour of a process. These include most control chart applications, the collection of production, sales and costing data and so on. This is not to say that decisions are not made on such data but that these data are used in conjunction with each other and with what are known as the "imponderables" to help in the running of a factory or business: that is, they are ancillary to the making of decisions.

The purpose of those tests which come under the second heading is much more restrictive: it is to assess the quality of material, etc., and on that assessment to take definite action. A batch of incoming material may be checked and if the tests show it to be unsatisfactory it may be sent back to the supplier or the bad material may be sorted out. A machine may be tested and the results used to re-adjust it. An outgoing product may be checked and if of lower quality than desired may be repaired or routed to less exacting customers. The important point to be grasped is that in this kind of test the procedure for making decisions is laid down in a clear set of rules (e.g., accept a batch if it contains less than 1 per cent defective items) so that junior staff can be responsible for its operation; also the tests, and hence the decisions, are usually confined to one component or batch.

The purpose of this paper is to discuss the characteristics of the second type; these tests, where they involve taking samples, are usually called sampling schemes.

IS IT WORTHWHILE TO INSPECT A BATCH 100 PER CENT?

The first question that arises is the advisability or otherwise of inspecting the whole of the batch of materials of which the quality has to be assessed. The alternatives are to inspect some of the batch or, in the limit, not to inspect at all. This problem is often answered in a vague way by saying: "It's too expensive to look at all of them"; or "We cannot afford to let bad items into the factory." It is the author's contention that in some cases, at least, it is worthwhile analysing the costs involved in order to see if optimum conditions can be reached—optimum in terms of minimum cost or maximum profit. Often there is no alternative to sampling; we are then faced with the problem of how many to test and also the question of how "good" is a sampling scheme.

HOW GOOD IS A SAMPLING SCHEME?

To start with, we assume that each article in the batch has an equal chance of being selected. If this is so we are assured that the sample will reflect the quality of the batch as a whole, although, because of the possible choices from a batch, there will be a certain amount of variation from one sample to another. Quite often this assumption gives rise to practical difficulties in actually making the selection. It is not sufficient in some cases to "take a handful off the top": the whole contents of the box may have to be spread over the floor and mixed up before taking a sample. It should also be pointed out that, although it is easy to conceive of samples being single units which may be separable from a consignment, a portion of a continuous whole, such as the section of a metal plate on which hardness tests are made for quality assessment, is equally a sample and the analysis of such tests follows similar lines.

The goodness or efficiency of a sampling scheme is described by a curve known as the Operating

* A lecture given to the Non-destructive Testing Group of the Institute on September 20, 1957.

Characteristic. This curve is a plot of the chance of accepting a batch against the proportion of defects or some other quality in the whole batch. Fig. 1 shows two Operating Characteristics, one for " accept 0/10 " and the other for " accept 0 or 1/150." An Operating Characteristic can also be derived for the case where measurements are made on a sample as distinct from counting rejects: an example of this is given later.

The technical details for drawing the curve are very simple and are described in most text books but brief details are given in the Appendix.

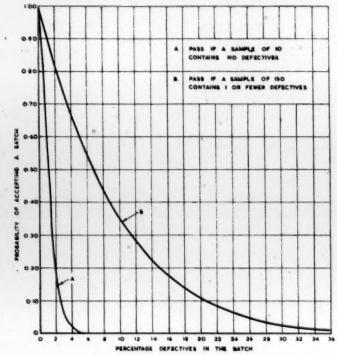
A PASS IF A SAMPLE OF 10 CONTAINS NO DEFECTIVES
B PASS IF A SAMPLE OF 150 CONTAINS 1 OR FEWER DEFECTIVES
PROBABILITY OF ACCEPTING A BATCH
PERCENTAGE DEFECTIVES IN THE BATCH

Fig. 1. *Operating-characteristic curves for two inspection schemes*

The point to be noticed about the Operating Characteristic is that the steepness of the curve is dependent on the number sampled, and the steeper the curve the better the scheme; this, of course, is in line with our intuition. Secondly we may move the whole curve to the right in order to alter, as it were, the pass level, by increasing the allowable number of defects (Fig. 2). Fig. 2 shows the curves for accept $< 3/10$ and $< 17/150$. The fundamental point is that unless the batch contains all or no defects, there is always the risk of making the wrong decision, and this risk is given by the curve.

It is usual to define this curve for purposes of description by two points: the " producer's risk " point and the " consumer's " risk point. The producer's risk point is that batch quality which will be rejected with, for example, a probability of 0·025. The consumer's risk point is similarly that batch quality which will be accepted with probability 0·025. These points are intended to correspond roughly with that quality which would generally be acceptable and that quality which would almost certainly be unacceptable—the reason for the choice of the terms " producer's " and " consumer's " is obvious.

If these points can be derived or guessed (it is usual to compromise), then all that is required is the solution of two equations of the form of (1) in the Appendix. This, however, is a laborious business, and although there are approximate methods which are very good the most painless way is to use a book containing a list of schemes each with its own Operating Characteristic.[4]

The important point about the Operating Characteristic is that it is a description of the sampling scheme and every sampling scheme as long as it is stated in explicit terms, no matter how complex, has an Operating Characteristic attached to it. There is no such thing as a *statistical* sampling scheme; it is the analysis of each scheme on its merits which is important.

The schemes discussed so far have been of the simple type where one sample is taken and the batch accepted or rejected according to the assessment of the sample. Schemes have been designed where, on the results of the first sample, one of three decisions may be taken to accept, to reject or to take another sample; the final decision to accept or reject is then made on the second sample. This procedure can be extended to the limiting case where samples are inspected one by one and each time a decision is made to accept, reject or

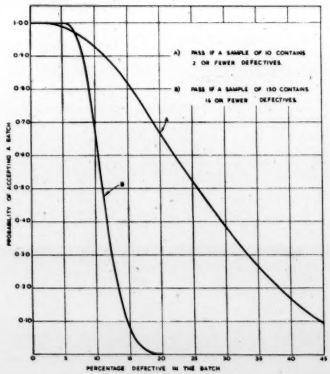
A) PASS IF A SAMPLE OF 10 CONTAINS 2 OR FEWER DEFECTIVES
B) PASS IF A SAMPLE OF 150 CONTAINS 16 OR FEWER DEFECTIVES
PROBABILITY OF ACCEPTING A BATCH
PERCENTAGE DEFECTIVE IN THE BATCH

Fig. 2. *Operating-characteristic curves for two inspection schemes*

take a further sample until the final decision is made. Such a scheme can be arranged to have the same Operating Characteristic as a given simple or single sampling scheme; the sequential type of scheme, however, where items are tested one by one, is generally the most economical in numbers tested. In the case of the sequential scheme the number tested is dependent on the quality of the batch: decisions are made quickly on good and bad material but the number tested rises at intermediate quality. It is apparent, however, that the sequential scheme may be difficult to organize and for this reason it does not seem to have found general favour.

AN EXAMPLE OF A SEQUENTIAL SCHEME

A factory within the Company is concerned with the manufacture of carbon rods for use in dry batteries—the kind which are used in torches. One of their problems is to ensure that the carbon rod is ground to a reasonably uniform diameter so that its brass cap may fit snugly. A checking scheme is desired to ensure that individual rods lie within the limits $\pm 0{\cdot}03$ mm.

The first step was to study the data which had been collected. This is necessary in order to ascertain that the grinding machine is capable of complying with the set limits. From the data it was decided that, provided the machine behaved itself, it could in fact attain $\pm 0{\cdot}02$ mm. The data implied that rods would be very satisfactory if the machine

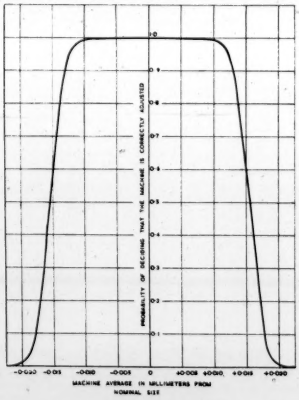

Fig. 3. *Two-sided operating-characteristic curve for the single sampling scheme ; that for the sequential scheme is similar*

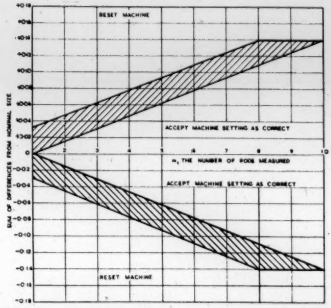
RESET MACHINE
ACCEPT MACHINE SETTING AS CORRECT
n, THE NUMBER OF RODS MEASURED
ACCEPT MACHINE SETTING AS CORRECT
RESET MACHINE
SUM OF DIFFERENCES FROM NOMINAL SIZE

Fig. 4. *Graphical representation of the sequential scheme*

average lay within $\pm 0{\cdot}012$ mm and very unsatisfactory if it were outside $\pm 0{\cdot}019$ mm. That is, our procedure is to measure a sample and on the basis of the measurements to decide either that :

(*a*) The machine is operating at the correct average.

(*b*) That this is not so and it needs adjustment.

The statistical problem is to find the limits for the sample average and the number to be tested. The limits for the machine average give us the Producer's and Consumer's risk points; in this instance we require a two-sided Operating Characteristic since both high and low averages are undesirable. The Operating Characteristic is shown in Fig. 3. The ordinate gives us the probability that on the results of testing the sample it will be decided that the machine average lies within the correct limits.

Two schemes which have this O.C. were designed.

(*a*) A single sampling scheme: measure 10 rods; if the average lies within $\pm 0{\cdot}0155$ mm of objective, leave the machine alone; otherwise reset it by the amount indicated by the sample average.

(*b*) A sequential scheme: measure each sample: if the sum of the differences from nominal size lies within the shaded areas in Fig. 4, take another sample; if the sum lies outside the V, reset the machine by an amount equal to the average difference found; if the sum lies within the V, leave the machine alone. A very clear exposition of the procedure for determining such tests is given by Hoel [6].

The sequential scheme was tried out in the factory, the machine being checked every quarter-

hour. After a morning's experience we found that we had to make a small modification; it seldom happened that a decision was made on the first sample and we felt that some form of "filter" was needed so that the checking scheme would be used only when likely to be necessary. The final scheme was to take two rods and only if the *average* of these two exceeded ±0·010 mm from the target was the full scheme to be used. In addition, the averages were plotted on a rough chart. In this way the mechanic was able to follow drifts in the machine level. It will be noted that this procedure diverges from the normal theoretical assumption that at the instant of the test the machine is treated on its merits at the moment. By using the chart, the mechanic was able to alter the frequency of his checking according to whether or not he thought there was a danger of the machine average drifting outside the desired limits. This modification alters the original operating characteristic slightly but not sufficiently to give rise to the occurrence of rods outside ±0·03 mm, and there was the added advantage that the organizational problem was eased.

Two points are worth noticing in this example. Firstly, there is a need to fit an abstract mathematical exercise into a practical situation. Secondly, the particular practical advantage actually gained from a rationalization of the checking scheme, was the brake that the scheme put on the mechanic's natural desire to alter the machine on insufficient evidence. It was very noticeable that, where the usual scheme of adjusting the machine on the basis of only two rods was used, the machine was altered very many more times than when using the sequential scheme: the results showed, if anything, a higher variability for the usual scheme. This is, of course, to be expected; if the machine average is altered on what may be the random variability of samples from a steady average, then the total variation is increased by swinging the machine average unnecessarily.

FURTHER COMPLICATIONS: WHAT ARE THE ECONOMICS OF A SAMPLING SCHEME?

It cannot be too strongly emphasized that the Operating Characteristic describes the behaviour of a sampling scheme under a set of hypothetical conditions. Hence the Operating Characteristic by itself is inadequate to describe what might happen in a real situation. In the last example, for instance, the Operating Characteristic alone was a sufficient guide because the machine was capable of complying with its requirements, when operating in its usual manner, and it was only rarely that the average changed sufficiently to require its being reset. We were thus able to work on the assumption that either the machine was working correctly or it was not. This is a very simple model of behaviour but adequate for the purpose.

The crux of the matter is whether we can assume that there is a "good" and "bad" quality batch between which we have to make a choice, the two qualities being the Producer's risk point and Consumer's risk point. If this is the case then the Operating Characteristic approach is sufficient. However, there are occasions when there is no sharp dividing line between "good" and "bad." Alternatively the cost of testing the number that this approach suggests may be thought to be too great. Again, the quality of the incoming batches obviously affects the choice of a scheme: if the incoming quality is always good, then there is no need to sample; if whole batches are never satisfactory, again there is no point in sampling but each batch must be sorted so that acceptable material can be salvaged.

These considerations lead to the question: "What is the most economic number to be tested?" To answer this question we require to know three things:

(*a*) The prior distribution of quality: this is the relative numbers of batches which are of "good," "indifferent" or "bad" quality.
(*b*) The cost of accepting a batch.
(*c*) The cost of rejecting a batch.

The concept of batches coming in at varying quality levels is a necessary part of the scheme, for if the costs are known and batches are all of equal quality it requires only simple arithmetic to determine whether to 100 per cent or not—sampling in this instance is of no value. Both costs include the cost of inspecting the sample: the cost of acceptance includes also the cost of accepting as good, a batch of bad quality; and the cost of rejection includes the cost of sorting out the bad batches, or throwing away good material, or returning the batch to the supplier.

If these three things can be determined then it is a relatively easy matter to build up a cost function.

Cost function =
(Cost of acceptance × Probability of acceptance) + (Cost of rejection × Probability of rejection).

This is a function of the sample size and the acceptance number, and a sampling scheme can

be chosen such that the cost is made a minimum. Wise analysts will not leave the matter here but will investigate the form of the function to see how errors in the assessment of the costs and prior distribution will affect the result.

AN EXAMPLE OF A COST FUNCTION

A travel bureau employs many agents up and down the country to arrange its customers' journeys. Periodically the counterfoils of the tickets and the remittances are returned to the central office. Here each counterfoil is checked to see that the right price has been charged. If it has not then a settlement is made between agent and company.

It is found that the cost of inspecting all the counterfoils equals the settlement for mistakes. Intuitively, it is felt that if a small sample of each batch were inspected and the results used to divide the batches into those that are worth inspecting 100 per cent in order to get the return on the errors, and those that are not, the company would gain financially.

The following symbols will be used :

N = batch size
a = average price of an error
b = cost of inspecting a counterfoil
p = proportion of errors in a batch
dP = probability that a batch has a proportion p errors in it.

$Pr\ [r \leqslant c \mid n,p]$ is the probability that a batch will be accepted and not inspected if c errors or fewer are found in a sample of n counterfoils.

The gain to the company, by using a sampling scheme instead of their present procedure, on a batch containing p errors is:

$$g = (-nb)\ Pr[r \leqslant c|n,p] + (aNp - Nb)(1 - Pr[r \leqslant c|n,p])$$

The total gain over all batches is

$$G = \int_0^1 g\,dP$$

Now

$$Pr[r \leqslant c \mid n,p] = \sum_{r=0}^{c} {}^nC_r\, p^r (1-p)^{n-r}$$

and it is convenient to assume that

$$dP = \frac{p^{\alpha-1}(1-p)^{\beta-1}}{B(\alpha,\beta)}\,dp,$$

$$\text{where } B(\alpha,\beta) = \frac{(\alpha-1)!\,(\beta-1)!}{(\alpha+\beta-1)!}$$

(This function can take a variety of shapes depending on the choice of α and β, which have to be estimated from data.)

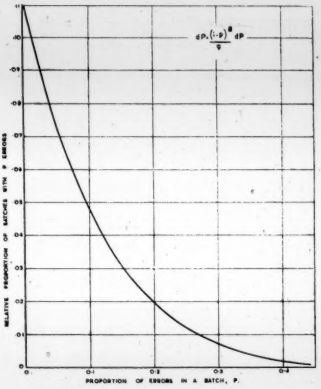

Fig. 5. *The prior distribution of errors*

It can then be shown that

$$G = aN\bar{p} - bN - aN\sum_{r=0}^{c} {}^nC_r \frac{B(\alpha+r+1,\ \beta+n-r)}{B(\alpha,\ \beta)} + (N-n)b\sum_{r=0}^{c} {}^nC_r \frac{B(\alpha+r,\beta+n-r)}{B(\alpha,\ \beta)},$$

where $\bar{p}$ is the average proportion of errors per batch over all batches.

The simplest approach at this stage seems to be to calculate G for several values of n and c and so find the maximum graphically. It is convenient, too, to deal with the ratio of the total gain to the total value of the errors; that is

$$\frac{G}{aN\bar{p}} = 1 - \frac{b}{a\bar{p}} - \frac{1}{\bar{p}}\sum_{r=0}^{c} {}^nC_r \frac{B(\alpha+r+1,\ \beta+n-r)}{B(\alpha,\ \beta)} + \frac{(N-n)b}{aN\bar{p}}\sum_{r=0}^{c} {}^nC_r \frac{B(\alpha+r,\ \beta+n-r)}{B(\alpha,\ \beta)}$$

This is in terms of the ratio b/a and does not depend on the absolute values of the costs.

To illustrate how this works out, suppose that $b/a = 0{\cdot}1$, $\bar{p} = 0{\cdot}1$, $N = 300$, $\alpha = 1$ and $\beta = 9$. These values of α and β give a J-shaped distribution with average $\bar{p} = 0{\cdot}1$ (i.e. 10 per cent) which is shown in Fig. 5. With $b/a = 0{\cdot}1$, it will be noted that 100 per cent inspection gives zero gain.

Figure 6 shows the results of calculating $\frac{G}{aN\bar{p}}$ for several values of n and c. From the graph it

can be seen that the best combinations are :

(*a*) Test 15: accept 1 or fewer defects; otherwise check the batch.
(*b*) Test 20: accept 1 or fewer defects; otherwise check the batch.
(*c*) Test 30: accept 2 or fewer defects; otherwise check the batch.

All these schemes give more or less the same recovery of errors, about 25 per cent of total possible gain.

The next step is to vary the shape of the prior distribution of errors and investigate what happens to the " gain surface " in the light of foreseeable changes in costs and incoming distribution. Two such cases give the following optimum conditions:

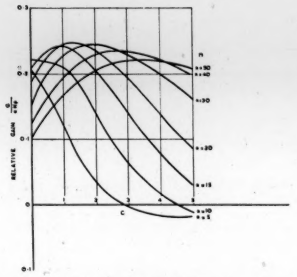

Fig. 6. *Relative gain against the sample number n and acceptance number c*

Prior Distribution	*Sampling Scheme*	*Maximum Gain*
(*a*) $p=0$ for half of batches and $p=0{\cdot}2$ for other half.	Accept 0 or 1 in 20	43%
(*b*) $p=0{\cdot}05$ for half of batches and $p=0{\cdot}15$ for other half.	Accept 0, 1 or 2 in 30 or accept 0, 1, 2 or 3 in 40.	10%

CONCLUSION

Every sampling scheme can have an operating characteristic drawn for it and this shows the " cover " given by the scheme. Conversely, if in a given context, two points on an Operating Characteristic can be determined then a sampling scheme may be designed which will give the required cover. Alternatively the " economic " number to sample can be derived by compiling a cost function; this is particularly useful where there is no clear cut distinction between good and bad batches or where inspection costs are a substantial proportion of the total cost of production. Some care, however, is needed in doing this and it is better to investigate the behaviour of such models over a wide range of likely behaviour than to rely on the exact mathematical answer. It is the author's contention that, even if the numerical results of such an analysis are disappointing, a study along these lines will of itself prove useful in throwing light on the nature of the problem.

APPENDIX

DRAWING AN OPERATING CHARACTERISTIC

Attributes

(*a*) The probability of picking c or fewer defects in a sample of n where the proportion of defects in the batch is p, is given by:

$$Pr(r \leqslant c \mid n,p) = \sum_{r=0}^{r=c} {}^{n}C_r\, p^r (1-p)^{n-r} \qquad \ldots (1)$$

for $n < \frac{N}{4}$ where N is the number in the batch.

For a sampling scheme: " Accept if $r \leqslant c$ for a sample of n," the Operating Characteristic is drawn by plotting $Pr(r \leqslant c \mid n,p)$ against p. It is convenient to do this using tables of the Binomial Distribution; references to these are given in the Bibliography.

Measurements

(*b*) Provided that the standard deviation is known and the distribution may be assumed to be Normal, the probability that the sample average $\bar{x}$, of n items, is less than a limit L, where the batch average is μ with a standard deviation σ, is given by

$$\frac{(L-\mu)\sqrt{n}}{\sigma}$$

$$Pr(\bar{x} \leqslant L \mid n,\ \mu,\ \sigma) = \int_{-\infty}^{} \frac{1}{\sqrt{(2\pi)}}\, e^{\frac{-x^2}{2}}\, dx \qquad \ldots (2)$$

The Operating Characteristic is drawn by plotting $Pr(\bar{x} \leqslant L \mid n,\mu,\sigma)$ against various values of

μ. It is convenient to use tables of the Integral of the Normal Distribution.[7]

DERIVATION OF SAMPLING SCHEMES

Attributes

(*a*) Theoretically two equations of the form of (1) have to be solved for n and c; that is

$$Pr(r \leqslant c \mid n, p_1) = 0{\cdot}975 \quad \text{and}$$
$$Pr(r \leqslant c \mid n, p_2) = 0{\cdot}025$$

where p_1 and p_2 are the Producers' and Consumers' risk points respectively. The solution of equations of this type is laborious and it is generally better, either to use a book of previously calculated schemes[4] or to proceed by trial and error, drawing the operating characteristic at each step.

Measurements

(*b*) If a scheme is desired for use with a sample average, the problem is eased considerably. We have to solve

$$Pr(\bar{x} \leqslant L \mid n, \mu_1, \sigma) = \int_{-\infty}^{t_1} \frac{1}{\sqrt{(2\pi)}} e^{-x^2/2}\, dx = 0{\cdot}975$$

and

$$Pr(\bar{x} \leqslant L \mid n, \mu_2, \sigma) = \int_{-\infty}^{t_2} \frac{1}{\sqrt{(2\pi)}} e^{-x^2/2}\, dx = 0{\cdot}025$$

where $t = \dfrac{(L-\mu)\sqrt{n}}{\sigma}$.

Use of tables of the Normal distribution gives, for these values,

$$t_1 = +1{\cdot}96 \text{ and } t_2 = -1{\cdot}96$$

Hence, given μ_1 and μ_2, it is easy to solve for L and n.

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Vol. 9, August, 1958

General Education and Physics in the Sixth Form*

By A. D. C. PETERSON, O.B.E., M.A.
(*Director, Department of Education, University of Oxford*)

It is always alarming to speak before a body of experts, but this is for me a more than usually alarming experience, since I am not only speaking before experts, but doing so to some extent at least as a fraud. All schoolmasters are familiar of course, and I hope undismayed, by the degree of fraudulence involved in teaching, as a stop-gap some unfamiliar subject in which it is necessary by hurried homework to keep one chapter ahead of the boys. My position is much worse than that, for I must in all honesty begin by saying that I have never had a formal physics lesson in my life except such as I have attended in the last few years as an observer. Indeed I was long doubtful what function I could fulfil at a physics conference except to act as a living and horrible example of the one-sided specialization that is the peculiar feature of our secondary education.

But I have been impressed recently in conversation with university mathematicians and physicists by the emphasis that they lay on teaching sixth formers to ask the right questions, rather than to know the right answers. The fact that this was the first principle that my own Greats tutors emphasized to me seemed to be an indication that the two disciplines were not so very far apart : and the principle itself gives me my justification for being here. For what I should really like to do this evening is to make some approach towards formulating some of the right questions to ask about physics and general education, and perhaps in the process to get from you the beginnings of some of the answers.

This involves me in at least stating the assumptions, as to the purpose of education, and particularly of general education, on which I am working. And I will try here to be brief even at the cost of being dogmatic. I am assuming then that the purpose of secondary education, of which I shall mainly be speaking, since I am one of those who believe that general education is unlikely to happen at the university unless it has been properly started at school, is three fold :

First, to impart skills and knowledge which are directly required at the next stage of the pupils working life—that is in employment or in higher education.

Second, to train the mind of the pupil so that he or she may best tackle and enjoy the new problems and experiences that the future holds in store.

Third, to provide happy and stimulating activity over a period of years when the adolescent is better kept out of the productive labour market.

There is one point about these assumptions which I should like to emphasize. Apart from the third, which is the least important, they are concerned with the future. And this is, I think, extremely relevant to the question of general education, and sometimes forgotten. It does not matter how much history a boy knows on leaving school unless he is going to read history at a university. And even then it matters very little. What does matter is whether he has acquired a sufficient taste for history to continue to read it in adult life ; and whether his study of history at school has contributed to the development of a capacity to understand human motives and causes and perhaps to a refinement of moral judgment. And yet it is knowledge that we tend to test and to value. In the scientific subjects, also, there is a growing agreement that one of the flaws in our present syllabus and system is that we put too much emphasis on knowledge and too little on the development of interest, curiosity, and judgment.

In fact we have been paying too much attention to the first of the three purposes of secondary education and too little to the other two. And that is why we now hear so great, and, I believe, so justified a clamour for general education. The other reason for this clamour is of course that in our schools—and in our schools alone throughout the world—it is possible, though not of course inevitable, virtually to abandon the study of the Arts at 15 or never to begin the genuine study of the Sciences at all.

* A lecture given to the joint Conference of the Education Group and South-Western Branch, in Bristol, on April 9, 1958.

There are, I think, two main proposals under consideration for restoring a more balanced general education to our specialized and one-sided Sixth forms—for the abandonment of specialization itself at this point is not, I think, under serious consideration at all. And I want to consider the position of physics in regard to each of these schemes. The first, which has the general blessing of the Incorporated Association of Headmasters and perhaps the less general blessing of the Headmasters' Conference, is that the traditional division of the Sixth into Arts and Science, with boys specializing in two, or more usually three, Arts or Science subjects, should be maintained ; but that two fifths of their time should be devoted to general studies, with the obvious idea of providing a balance to their specialist work. It seems to me that an essential corollary of this scheme is that the content, though not the intellectual level, of the specialist requirements should be slightly reduced, in order to provide the extra time for general studies.

The other also starts from this corollary, if you can start from a corollary, but suggests that the essential reform is to break down the barrier erected between the Arts and Sciences and that if the extra time were used for this a general education could be derived from a balanced group of specialist studies.

It would be tempting to embark on a discussion of the relative merits of the two schemes, but I will try to stick a little closer to my last than that, and to examine specifically how they would affect the teaching of physics in schools. And if certain merits and demerits of the two proposals emerge that will, perhaps, be no bad thing.

Under the first scheme, therefore, we must assume that the schoolboy—or girl—physicist will be taught very much what he is taught now, but less of it. On an average, those who do physics in the Sixth form probably spend about three-quarters to four-fifths of their working time (in which I do not include games, C.C.F. or such activities) either on physics, mathematics and chemistry or on physics and mathematics. They will have to reduce this to three-fifths to make room for the general studies. Is this then the first question that we ought to be asking ? Can this reduction be achieved without disqualifying, in its real sense, the Sixth former from entry on a degree course ? Or is the standard of attainment in physics which university Faculties are at present demanding really higher than they need ? All my hunches tell me that the answer to both questions is " Yes," but I cannot claim to support those hunches with empirically verifiable evidence. A lot of work needs to be done on this question and it forms in fact part of an enquiry into Sixth form specialization which we shall be carrying out at Oxford over the next 18 months. The probability that Faculties are requiring a higher standard, not of ability but of training, than they need, arises from two factors. The first has been very well expressed by the late Professor G. B. Jeffery in his last and post-humously published work :

" It is not right for a university to determine the scope and nature of its courses solely in relation to its own internal economy, and with a view to securing the highest possible standards of academic attainment in its various fields of study. Yet something like this can be discerned as a general tendency in all universities, and it would not be difficult to find instances in which tendency is too light a word. One can see how it comes about. University teachers, speaking generally, have little understanding of the educational work of the schools from which their pupils come. They are fired with enthusiasm for their respective subjects, and, through the experience of their own researches they are ever conscious of the rapidity of the advance of knowledge. Their anxiety is to get their abler students as far as possible during their undergraduate courses. There is a constant tendency to raise the standard at the degree level, and then, under limitations of time, to raise the level on entry to the course. The schools are left to keep pace with this process as best they can."

The second factor constantly pushing the requirement up is the fact that entry to physics, engineering or mechanical sciences Faculties is in this country frankly competitive. Even the standard which this or that Faculty thought it was setting three years ago is no longer the standard that will actually admit to-day, and Headmasters are only too familiar with the answer that Jones has got the minimum qualifications all right but that there are others with better qualifications and only a limited number of places. What that means in terms of our national future I will not attempt to discuss here ; but it *must* mean that the standard actually exacted from Smith, who got the place, is higher than was essential.

I may be met at this point by the university argument that we are already " scraping the barrel." Again I must omit the interesting question whether our British barrel is really so much emptier than the Russian or American. Quite apart from that, the argument is, I believe,

irrelevant. Let us assume Smith, the bright boy whom you take, Jones the plodder who "qualifies" but who finds no place or just scrapes in as a barrel scraping, and Robinson who just fails. When you talk about scraping the barrel, you are not really talking about the amount of Physics they know, but the amount of potential ability in Physics they have got. Reduce the time allowed to it at school and if you like, though it may not be a necessary corollary, the level of attainment, and they will still occupy the same positions in your entry list.

I am going to assume, therefore, that the reduction of time devoted to physics in the sixth form, required equally by both proposals, is practicable without seriously incommoding the university Faculties at all. In considering the first proposal, then, there remain I think three questions to answer :

(*a*) What will the 40 per cent of general studies contribute to the education of the physicist ?

(*b*) What part will physics play in these general studies and so what will it contribute to the general education of the Arts student ?

(*c*) What does or should Physics itself studied as physics contribute to general education?

It is here that I must confess my first reservations about this whole scheme. They arise when one asks of what the general studies are to consist. The common answer is something along these lines : religion, philosophy, a foreigh language, English, economics, modern history, political theory, art, music, civilization of the ancient world, history and philosophy of science, and so forth. Clearly no Sixth form could study all of these even in the most general way and a selection would always have to be made in accordance with the interests and abilities of the school staff. And the list could, of course, be enormously expanded. But two things are very obvious about this list. The first was immediately spotted by Dr. Willis Jackson at the Brasenose Conference when it was first proposed and when it was assumed that four or five such lines of study would be combined in general studies. It was that four-fifths of the General studies would consist of more Arts subjects and that they would therefore do little or nothing to redress one-sided specialization on the Arts side or eradicate scientific illiteracy—which is in my opinion a much more real and more dangerous phenomenon than the supposed illiteracy of Scientists. The second trouble about the list is in my opinion that a great many of the " Subjects" are simply normal Arts subjects already being studied in the Sixth as specialist subjects. And I find it very hard to see how German, history, or English, studied as a general subject differ from German, history, or English—except possibly in not being taken very seriously. And I wonder whether those who are enamoured of the proposal are not falling into the trap of considering content of knowledge rather than development of the mind. To revert to physics, however : the young physicist will get under this scheme a " general " acquaintance with a variety of Arts or " humanist" topics and some introduction to the history and philosophy of science. And these will, I hope, be examined at " A " level. For if the new 40 per cent general studies were to form an oasis of unexamined work in the Sixth, I feel tolerably sure that it would be put to the proper use of oases—a loaf, a jug of wine and thou. Not that I am against intellectual loafing. The Sixth form could probably do with more of it. I think we might indeed consider less time devoted to formal academic work and more to student intellectual clubs. But a system by which the *work* of the Sixth was divided into three-fifths on one side of the fence which *counted* for examination purposes and two-fifths on the other which didn't, would too often lead to cramming on one side and distaste or contempt on the other. I often wonder why university dons who assume that the whole of an undergraduate's work will be examined in his finals, are often so idealistic about freeing some part of the Sixth form's timetable. Would they, I wonder, support a proposal that one of the three Sciences in the first part of the Natural Sciences Tripos, should continue of course to be treated with equal importance by the students but should not actually be examined ? And yet undergraduates are presumably more responsible people than schoolboys.

There is one point in answer to our first question which leads on to the second. What is this history and philosophy of science to be ? Should it be taught as a general subject or as part of the science course ? And can it be taught to those who have done no science at all beyond the present—surely woeful—" O " level syllabuses ? These are very important questions, for the history and philosophy of science is the only contribution which it appears at present that physics, or indeed any of the sciences, would make to the 40 per cent general studies. I can do no more than pose the question and again suggest some pointers towards an anwer. The policy statement issued by the Science Masters' Association clearly believes that it can, but seems to envisage at the same time a broadening of interest in the specialist science courses. On the

other hand there is much in what Professor Vick has said : " To understand what science is and how a scientist thinks a student must *do* some science, not just read about it, or study only the history of science." And I wonder whether Professor Vick would regard an " O " level pass in physics-with-chemistry as really " doing some science." Einstein after all said much the same thing : " If you want to know the essence of scientific method don't listen to what a scientist may tell you, watch what he does." I must confess that I see some attractions myself in introducing the history of science into both the history and the science syllabuses, but I shall speak of that in discussing the second alternative. Finally then, what contribution does or should physics, studied as physics, make to a general education ? Here I am on much more dangerous ground, and in fact can only ask *you*. And before I do so, I propose like Socrates in the Republic to break off into a long digression, which will in fact be to describe the alternative plan for reforming the Sixth form ; for in that physics as an educational instrument would be used as physics and not as an element in general studies. The second plan of reform, the breakdown of the Science/Arts barrier is based on two assumptions:

The first is that from the point of view of content and understanding, the great majority of people want, and should have, an education which excludes no major interest of the modern world.

This is again an unproved assumption, a hunch. The opposition to this second plan seems to be mainly based on the belief that they do not want anything of the sort, and that English boys and girls naturally divide themselves at the age of 15 into those who have no further interest in the natural sciences and those who have no further interest in the humanities. There is little point in arguing this for the moment and it is also one of the subjects of the Oxford enquiry of which I spoke. For the moment we must simply recognize that the second plan is based on a hunch that this is not so.

The other assumption is that the value of a general education lies not so much in the acquisition of general knowledge, as in a general training of the judgment. Here, again, we are on the edge of deep philosophic waters but I do not think it would be too gross a simplification to suggest that to maintain a right balance, the higher stage of secondary education should be training moral, logical, experimental and aesthetic judgment, and introducing boys to the way in which such judgments are made in the modern world. It would be possible, of course, to train all these forms of judgment in the discipline of one subject—the classics, for instance. But there is no earthly reason why one *should* do so and the use of literature for training scientific or experimental judgment has in my opinion done much to impede its proper function of training aesthetic or moral judgment. The more practical system would seem to be to use literature and history to train aesthetic and moral judgment, language and mathematics to train logical judgment, and the natural and social sciences to train experimental or scientific judgment.

Acting on these two assumptions, therefore, what we propose is that less rather than more time should be devoted to formal " General Studies " but that every Sixth former should take four specialized subjects of which one at least should be what is now regarded as an Arts subject and one at least what is now regarded as a science subject. These would occupy 80 per cent of his time, the same amount of time per subject as is allotted under the other scheme. It would involve certain changes in the border lines between " A " level subjects on the Arts side which are hardly relevant in detail here, and which in any case need a lot of careful thought and negotiation. It would mean, however, that the Sixth former's general education would in fact be acquired by the spread of his specialist subjects. There would be no reason for instance, why two boys going to Oxford, one to read Greats and one to read physics, should not both have taken as " A " level subjects at school, Latin, Greek, physics, and mathematics : nor why two boys, one going into accountancy and one to read economics should not both have read mathematics, German, geography, and European history.

As with the other proposal, I should like now to try and formulate the questions which we ought to be asking from the point of view of physics. You will remember that we broke off with the third question arising from the other scheme, which now becomes the first and most important question :

(*a*) What does, or should, physics itself, studied as physics, contribute to general education ?

A great deal will depend on our answer to this, since we are now looking for general education not as an adjunct to, but as a product of, our specialist studies.

(*b*) Can we provide from four specialist subjects a genuine general education, or will it be necessary to provide some general factor over and above what he derives from these, in the 20 per cent of a boy's time which remains unallotted ? Incidentally, it would be fair, I think, to assume a

35-period week so that we have here seven periods a week to draw on.

And now at last I can no longer conceal my ignorance and can only throw out the suggestions of a scientific illiterate as to what physics might have done for my general education and might now do for the general education of others if given the chance. And if I am talking nonsense I rely on you to tell me so. I mean that in all sincerity. But if I seem to you to be talking sense, I shall be much relieved and rely on you or some other physicists to put some flesh on these bare bones.

First, then, from the point of view of content : it seems to me, as an outsider, that more and more physics is becoming the ultimate language for describing the real as opposed to the apparent nature of the material world. Is it not true that biology seeks for a simpler and more universal answer to its problems in chemistry, and chemistry in physics ? Is there any validity in the suggestion that the ultimate conceptions of physics present something closer than we have ever got to that purely intellectual formulation of the pattern underlying the world of phenomena, for which Plato was seeking ? These are questions I must ask you. But if this is so, and if physics is the study which underlies all other description of the material world and in which it ends, then surely every educated man should, if he can grasp it, learn something of the picture of the material world which physics presents. And I hope that this is not beyond the capacity of the Sixth form. In deciding how much they can be expected to grasp we must I think, try to strike a balance between the degree of detailed knowledge which is really required at this age from the future physicist and the grasp of the general picture which we can hope to give to, shall we say, the future Bishop.

But I do not regard content as the most important criterion. Physics can surely contribute two experiences of very great importance to general education. The first is understanding of scientific and experimental method, along with some actual experience in technique—though I am sceptical myself as to the degree of importance we should attach to technique and therefore to laboratory practicals as opposed to demonstrations. The second is a clear understanding of the difference between logical and practical judgment, as exemplified in the relations between physics and mathematics. This seems to me to be of prime importance to general education and is one reason why I am more inclined to favour the history of science as included in the science syllabus than as a separate subject. I feel that the boy who has the historical relationships between physics and mathematics really brought home to him as he studies those subjects will absorb it, as it were, into his intellectual bloodstream in a way that he may not if it is presented as an extraneous subject. I cannot explain better the sort of thing that I have in mind than by quoting from a most stimulating broadcast given on the Third Programme two years ago by Mr. Hanson, the Lecturer in the Philosophy of Science at Cambridge :

" This failure to discuss the foundations of geometry has a devastating effect on the student. Anyone who fails to grasp the relationship between mathematics and physics at this level will fail to understand the connections between experimental confirmation and mathematical proof in advanced physics.

He will never, for example, appreciate Kepler's achievements. Kepler practised what Plato preached, reducing complex clusters of phenomena to mathematically clean and simple conceptions. After realizing that Mars' orbit wasn't circular, he thought it moved in an ovoid, or egg-shaped, path around the sun. No geometer at that time could manage the equations of such a curve. So he did something that would be second nature to every theoretical physicist to-day. He treated the orbit as an approximation to an ellipse, whose formal properties had been set out by Archimedes. This egg-shaped curve actually failed him. Nonetheless it marks the real wedding between mathematics, and experiment, a marriage that has grown indissoluble for physics. The nature of this union to-day will not be noticed by the man who cannot distinguish, as Kepler taught us to do, a physical hypothesis from the purely mathematical reflections which shape and polish that hypothesis. Such a man will never really understand the role played by mathematical theory in quantum physics, in atomic research, and in theoretical chemistry. These more advanced battles can be prepared for, however. The schoolboy who can think Kepler's thoughts may one day give the world a few of his own."

Finally for those who have this wide spread of subjects, normally, I would suggest, including physics, is anything further in the way of general education needed ? I would suggest very tentatively that three of those seven periods should be given to religion and philosophy and that the small extra time over the amount usually allotted should be devoted to an attempt to make explicit the different forms of thinking, the different types of judgment and evidence used in the specialist subjects. We hope that our students are going to

absorb a general education from exercise in widely different modes of human experience ; but this assumes that they *can* extract a training from such experience and transfer it to new experiences of their own. And it is by now an educational truism that, at more elementary levels, transfer of training takes place only when the common elements to be transferred are made explicit. I believe that in the Sixth form we want to take a leaf out of Field Marshal Montgomery's book and take the troops more into our confidence as to the objects of the exercise.

And the last four periods ? Do you think we could spare them as an oasis ? Apart from literature our Sixth formers are often aesthetically starved and I wonder if they could not be made available for music, painting, crafts, drama and so forth but conducted, not so much as an additional but unexamined subject, but as a student club activity. Our great boarding schools have often facilities for serious artistic or intellectual clubs of this kind which it is hard to provide them after hours in the City grammar school.

I am afraid that I have talked far more about general education than about physics, and you must ascribe it to the shockingly one-sided education that as a classical scholar I received at school. At least like so many fathers I am anxious that the mistakes my son makes and suffers from should be different from my own. And that is my sole justification for being here and for having absorbed so much of your time.

Physical Society Conferences

Members of the Institute are invited to attend the following three conferences, full details of which may be obtained from the Secretary of The Physical Society.

Sept. 17-20	**" Discharge Physics "**	At University College, Swansea
Sept. 24-25	**" Cosmic Rays "**	At the Durham Colleges, University of Durham
Dec. 18-20	**" Interfacial Phenomena "**	At the Cavendish Laboratory, Cambridge

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The Step from School to University*

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INTRODUCTION

NOWADAYS far too many university entrants come from school. There are indeed very few students who do not come direct from school to university. This means that the population is very young in experience and, perhaps more important, much too uniform in composition. There is little sense of purpose. I do not mean this, necessarily, in any high moral sense but simply that very few have seriously examined any alternative. They come to the university because they get a grant and a place. This is not the fault of the young people themselves of course. Inevitably the whole educational structure has to some degree become treadmilled but surely leaving school is a time to take breath, and in taking breath, take thought. It is a serious problem, and it will become worse, to prevent University education from being treadmilled. It requires unceasing effort to persuade students, and it must be by persuasion not rote, that they have become members of a Department in order to acquire an appreciation, a grasp of a branch of human knowledge and not because they are sheep who expect to be driven through the hurdles to the shearing of an examination. The conception of staff as journeymen and students as apprentices is not only foreign but to many of them silly. I find that the mediaeval practice of an apprentice's " masterpiece " in the form of a small original investigation pursued, in the third year, *ab initio* has a remarkably good effect. It emphasizes that it is the thinking not the syllabus that matters. I am sure these problems and these complaints are not new but their impact is much sharper under present and impending circumstances. The uniformity of experience and background make it much worse because the young are much less capable of helping themselves ; if some of them were in different boats they would at least appreciate that there *are* different boats.

It must be confessed that the universities are far from blameless in this matter. The pressure on available places, much exaggerated by multiple applications, means that there are something of the order of five applicants for each place. The purely administrative problem attracts a purely administrative solution, the tidy solution in terms of performance at Advanced Level in the General Certificate of Education. In my opinion this is not only unfair in many cases, it is disastrous. It is unfair to the young man with the unusual (" abnormal ") qualifications, background and experience, the very qualities necessary to help his colleagues.

Consumers of goods frequently complain, it is the privilege of consumers and we frequently receive complaints about the quality nowadays of university graduates. They never were of course what they used to be, but I am very conscious of a feature which has become marked since the War, a feature of the changing position of the university in the community, a feature of the rising proportion who come to the university. Not many students have a conception of a *professional* job of work. There is too much time-serving ; few grasp that it is the problem that counts not the hours, that it may take a day or a week or a month or a year but that the purpose of the exercise is to solve that problem. Few realize that a " professional " lives with his work. This is probably the single most important task of a university education, it is the real meaning of an academic discipline, it is a matter of *values*. Success can only be achieved by catching the imagination. If we teach university students a sense of professional responsibility and show them that the subject is both exciting and tremendous fun, we succeed. They can spend the rest of their lives learning some Physics. After all, that is what we do ourselves.

UNIVERSITY ENTRY

There is much heated argument at the moment concerning entry to universities ; it has been discussed at many conferences[1] and will doubtless be discussed at many more. Certainly getting a place at a university is fundamental to the transition from school to university but if we start this morning to discuss this in general terms we shall talk of little else. My own view is that, at the moment, the difficulty is much exaggerated.[2]

* A lecture given to the joint conference of the Education Group and South-Western Branch, in Bristol, on April 11, 1958.

It is very important that the young people should be free to choose their university and the consequent multiple applications distort the real picture.

Let me refer to two features of the problem as it affects Physics. There are in England and Wales some 1,856 schools preparing candidates for the universities. These are made up as follows[3, 4] :

1,193	grammar schools
298	technical schools
170	direct grant schools
195	public schools
1,856	

An estimate of the total number of places in the various Honours Schools of Physics in July, 1955 was[5] 750 ; this number is increasing and at the moment I am told that it may be of the order of 1,400. It follows that there is still less than *one place per school*, and until the last year or so it was nearer half a place per school. I am not arguing that the number of places is, at the moment, either adequate or inadequate ; I am not talking of the future and the plans for expansion. I am simply trying to present the factual position which is that few candidates who sit the Advanced Level papers in physics proceed to university to study physics ; in 1956, the proportion was roughly[4] 1 in 21 or about 5 per cent of the entries and about 1 in 14 or about 7 per cent of the successful candidates.

The university population is increasing. " The proportion of the age group remaining in the sixth form has increased by 5 per cent per annum for the last three or four years."— To this pressure must be added the effect of the " bulge." These are general problems to which the University Grants Committee and university authorities are giving attention. In this broad background, the position of physics is particularly challenging. The place of physics in the educational framework is changing. In terms of the numbers of candidates sitting or successful at the Advanced level of the G.C.E., it is now much the largest experimental subject[4]. In passing, note that the position of girls is quite appalling. The proportions of girls in 1956 were as follows— :—

Proportion of girls of total entries at O Level: 44·5%	Proportion of girls, O Level, Physics : 12·6%
Proportion of girls of total entries at A Level: 30·3%	Proportion of girls, A Level, Physics: 13·7%

The growing popularity of physics is reflected in figures quoted by Sir Edward Boyle, the Parliamentary Secretary to the Ministry of Education when comparing numbers of Advanced level passes for 1956 with those for 1951 :[8]—

	Boys	*Girls*
Increased passes in history ...	9%	22%
Increased passes in French ...	17%	15%
Increased passes in Physics ...	46%	66%

It means that of the impending flood which will fall upon the universities, a particularly high proportion will seek places in departments of physics. On all hands we are told of the crying need for more scientists and technologists. Personally I should be the more impressed by these cries of distress if they were supported in an old-fashioned economic way. Young science graduates are certainly offered jobs which are not unattractive economically but it is remarkable how many leave purely scientific fields of endeavour and how quickly ! Certainly there is a real national need, of that we cannot doubt. And it is also certain that there will be an expanding number of applicants. The profession must guard their interests.

SCHOOL

Both schools and universities share one problem to which, I think, neither has given sufficient attention. In all sciences there are at least two distinct types of student. There is the potential professional who must know in order to do and the majority who seek to know in order to appreciate. We cater too exclusively for the professional. In schools, few, very few, according to the figures I have quoted, ever hope or intend to be professionals. Hence surely the aim should be appreciation, what physics can do and how we go about it. Don't misunderstand me ; I am not advocating an amiable course of physics-without-tears. No one can appreciate the discipline of an experimental science without doing some experiments. But it is not necessary to have an *extensive* training in experimental techniques to appreciate " the experimental method." It is a constant surprise in interviewing applicants to find large numbers who have seen many experiments carried out before them but who have performed few, often none. The cause I imagine is cost of apparatus. Much can be learnt from fewer witnessed experiments and more actual breakages. It is part of a general education to know something of physics and just as we can learn to appreciate music without playing an instrument, so we can learn to appreciate physics without becoming a physicist. The schools will say, what about the A-level and university entrance ? As I understand it, the A-level

examination was designed as an end in itself. Certainly it should be and most candidates use it as such ; they do not come to the university. It is a qualification and not a competitive test. University selection is not, never was and never will be solved simply by examining marks in the A-level examination.

I would ask the schools to do three things, and continually hope that they do. The obvious first request is that the young should be able to read, write and count. This is often mentioned and just as often treated as an amusing aside, but I mean it very seriously. Very, very few young people seem to grasp the point of being able to read with understanding, to write with clarity and count with accuracy. I have some sympathy for a boy who can't add ; I have to check my own invariably. I have no sympathy whatsoever for a potential scientist who does not appreciate quantitative accuracy and regards adding up as a tedious chore.

The second request is to prepare candidates to study physics as a whole. The experiments of co-ordination which characterized the XIXth century brought the subject to maturity. It is difficult to decide whether the schools or the universities are more to blame for the confidence trick that seems to be worked. Undergraduates seem to expect university physics to be school physics, only more so. It is *not* applied mathematics, it is not the discrete study of heat, light, magnetism and electricity. It is the primary study of natural philosophy based on experimental laws. At school certain tools are fashioned, at the university they are used.

Finally—and in this I feel that we in the universities do have some grievance—please examine with the young person whom *you* know whether he does really want to study physics. Because physics is a fundamental science, many applicants think they want to study physics when they don't, they want to study mechanical engineering or electrical engineering or aeronautics. I have my own views on how mechanical engineers, electrical engineers and such should be trained ; my present point is the purely practical one that the young man concerned won't get what he is looking forward to in a department of physics.

UNIVERSITY

Universities have many faults. Perhaps the most drastic change that a newcomer encounters is the simple consequence of size. From being the apple of the eye of his sixth form master, he becomes number 112 in a class register. The change in itself is no bad thing if he is warned, if he realizes that the system is based on the old-fashioned doctrine of " enlightened self-interest." Nevertheless universities are nothing if they do not develop the individual qualities of their numbers, if they do not assist each to make his own contribution.

The number of staff in a university department is limited. In the next ten years there will be a considerable expansion. I sincerely hope that the additional staff will not be used to add materially to the load of lectures. I should like to see much of the effort devoted to personal supervision of second and third year students. A student in his first year should be largely left to come to terms with himself ; he must sometime and the sooner the better. There is much alarm among schools and Local Education Authorities that many candidates are rejected at the end of the first year. There are many factors which contribute to this and, without committing myself to a particular percentage, I would like to turn this round and ask the schools and the Local Education Authorities if they would prefer that universities should encourage people to proceed whom they are convinced will fail ?

The subject should be taught as a whole but this does not mean that we profess to teach the whole subject. The field is much too large. We are continually told by this, that and the other interest that not enough attention is paid to some particular field. I am quite unrepentant. I would not begin to try to drag any class of students through all the thickets of physics ; it would be idiotic to try. What we should aim to do is to ensure that a student with a good Honours degree is in a position to tackle any branch of Physics. And for this purpose it is necessary that he receive guidance in the more sophisticated branches of the subject and be compelled to acquire some mastery of one.

This brings us to the perpetual problem of the Honours syllabus. The temptation to expand the syllabus is unending. This is as it should be ; if it is not unending there is something wrong with the department or the subject. But the time available is limited and there are some who demand a fourth year. The request is unrealistic and in my opinion rests on a poor foundation. What changes is the emphasis and honours courses ought, to some modest degree, to reflect these changes of emphasis. I think it is bad if undergraduates receive a high measure of specialized study ; it spoils their balance and appr ciation of the subject. What is seriously lacking in this country is proper systematic courses

of postgraduate instruction. Here I think, the British universities have fallen seriously behind those on the Continent and in America. In my view this is the place for the particular specialisms offered by the Department. In most universities the mechanism lies ready to hand in the form of a Master's degree by examination and dissertation. It is only then, after they have completed a relevant course of systematic, postgraduate teaching that students should be accepted for research and for the Ph.D. They should then be expected to do some original research for the Ph.D., not merely turn the handle of a sausage machine.

CONCLUSION

Three factors bear on the step from school to university now and in the near future. An increasing proportion of the young population are seeking university places ; there is an absolute increase of numbers, the bulge, passing through the schools who will seek university training. Finally, the supply of potential physicists increases steadily. We are told of a rising demand for physicists and applied physicists. It would be safe to conclude that we are, professionally speaking, living " in an expanding economy. At the same time the subject itself has grown to such proportions that we must examine seriously the question of whether or where and at what stage in our training divisions should be made. I hope we shall always train undergraduate students in the fundamentals of physics, indeed we must but there is a need to particularize at a postgraduate level.

The university pattern has greatly changed in the last twenty years. When the position in 1938 is compared with that of 1958, the change is dramatic. This appears to be inadequately appreciated in the schools where advice is given in the light of the personal experience of a previous generation. The support from government, charitable foundations and industry alone is now roughly that of the University Grants Committee before the war and accounts for some 20 per cent of the resources of scientific and technological departments.[9] That of the University Grants Committee is over twelve times what it was before the war and increasing rapidly ; a building programme to cost £60 million has recently been announced.

The English universities are unusual. As part of the tradition that a university is the place for a liberal education, they accept responsibility for the living conditions and " moral welfare " of their students ; it follows that some associated discipline must be imposed. This is not the custom on the Continent or in America. Furthermore the great expansion at the turn of the century coincided with the demand for technological education which was indeed one of the important forces behind the expansion. The continental countries had consciously devised an additional component to their educational framework, the technical high schools and colleges of technology as an integral part of the effort to overtake the English Industrial revolution. Because of the start this country had, the need was felt later and the civic universities acquired responsibility for higher technological education. " The modern English university is searching for a compromise between three ideas of university education acquired in the nineteenth century : the idea of the university as a school for the liberal education of gentlemen in character as well as intellect ; the idea of the university as an institute devoted to objective and disinterested research, inherited from the German idolatry of *Wissenschaft* ; and the idea of a university as a staff college of technological experts and specialists inherited from the continental polytechnic. It would seem that the modern English university will not admit that these three ideas may not be compatible."[10] In the popular mind the prototypes of these three are perhaps Oxford and Cambridge, the Institute of Advanced Study and the Massachusetts Institute of Technology.

This background should be appreciated. The universities are in the middle of the second expansion and upheaval. Their position in the community is changing and changing rapidly ; it will change more rapidly in the next ten years than it has changed in the past. The simple question of government presents new problems—a university of modest size of 2,500 students has an annual budget of over a million pounds. This is " big business " ; yet the simple master and scholar relationship must be preserved. Much the largest proportion of the money comes from public funds and university policy must therefore take into account what the public considers to be its interests. The purpose and place of a " university education " are being re-examined and modified. Revolutionary times are exciting. They are also times of stress. We must try not to make too many blunders !

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Reviews of Books

COMMUNICATION, ORGANIZATION AND SCIENCE

By Jerome Rothstein : with a foreword by C. A. Muses

Colardo : The Falcon's Wing Press. Pp. 110 + *xcvi. Price* $3.50.

This is a somewhat curious book in that the foreword and preface between them account for nearly half the total number of pages. But considerable justification can be urged because the subject-matter is unusual. Broadly, as the title indicates, the author is concerned with communication theory and one suspects (rightly as it happens) that cybernetics and the various computing systems now in vogue would be closely involved. All this, and much else besides, is fairly straightforward. What however is new is that a claim for the near-identity of all knowledge is implicit in the later chapters. For such a vast theme, the treatment appears rather slight : the style, however, is engagingly modest, and this makes the reader attentive rather than unsympathetic.

The thesis is that organization, or the lack of it, is basic for all human activity, humanistic as well as scientific ; and that its measure is entropy. We are familiar enough with the modern view that the concept of a " heat-death " need not apply universally (that is really the treatment of thermodynamically " open " systems) ; the element of novelty enters when such a mental tool as " order-disorder " is applied to such subjects as games, strategy, salesmanship and the social sciences.

It is of course well known that Leibnitz envisaged some kind of universal language—originally designed perhaps for use in diplomatic exchanges —which led in process of time to George Boole's Laws of Thought, and the whole technique of the propositional calculus. Philosophers may or may not have taken proper advantage of such a powerful mathematical weapon, but there is no doubt—as Mr. Rothstein says—that the engineers have seized upon it as well-nigh perfect construct for the solution of intractable network problems.

From this viewpoint, one may scan the author's own horizon with regard to the arts. He is perfectly correct in casting about for the place of rhythm, balance and so on ; what he seems to have overlooked is that here too, if Energy and Organization are taken as $y = f(x)$, the area under the curve is of the nature of a potential and subject to an *extremum*, such as one would readily expect in any canonical system such as that of Willard Gibbs. (Incidentally, no use is made of the theory of dimensions, which can be very significant when only the form, and not the quantities, of an unknown relation is being sought).

The present reviewer has followed this line of thought for several years, in some detail, using the *Gestalt-concept* as the machinery. It leads to worthwhile results if combined with the law of prägnanz; otherwise the very strength of the interpretative principle is apt to be frittered away.

Concerning the rather terrifying prospect that there is no theoretical impediment to the construction of a machine having such human qualities as thinking, experimenting, selecting and so on, the repulsion commonly felt is perhaps not wholly on account of these properties as upon the supposition that a Robot can be built to which it *matters* that, if it thinks, its thought are true.

The presumption is axiological rather than purely mechanical. And this is probably why " ultra " problems will always tend to find their way into some system of metaphysics, however unfashionable such systems may be at any given moment of history. The computers have yet to explain man's capacity for sacrifice, and *a fortiori* to evolve a machine deliberately to will it.

F. I. G. Rawlins.

NUMERICAL ANALYSIS

By D. R. Hartree

London : Oxford University Press. Second Edition. Pp. xvi + 302. Price 42s.

It is fitting that this second edition should appear so soon after the author's untimely death since it reflects so much of his interests and personality. The book is essentially a record of the late Professor Hartree's teaching of numerical analysis in Cambridge. There are many books on this subject in these days but this one is outstanding for its severely practical approach so typical of the author. This is the book for those who wish to practise numerical methods rather than to read about the formal theory of them.

There are a number of additions to the first edition. Gaussian quadrature formulae, using values of the integrand at unequal intervals in the independent variable, are treated more fully, as also are differential equations with two-point boundary conditions. The chapter on partial differential equations has been enlarged. An introduction to Whittaker's cardinal function has been included. The final chapter on automatic digital computers has been considerably shortened in view of other publications on the subject.

This is likely to remain a standard textbook on numerical analysis for many years.

J. CRANK.

THE GEOPHYSICAL JOURNAL

London : The Royal Astronomical Society

This is a new journal intended for the publication of papers on research and progress in geophysics and related subjects. The many and varied papers dealing with the practical applications of geophysics in the widespread search for minerals, oil and water, for foundation purposes and other projects, are catered for by excellent publications such as *Geophysics*, published by the Society of Exploration Geophysics in the U.S.A., and by *Geophysical Prospecting*, the official journal of the European Association of Exploration Geophysicists ; but with the rapid developments taking place in geophysics there is a real call for a British journal which affords speedy publication of papers of a more fundamental nature concerning academic studies relating to the earth and its atmosphere and on advances made in geophysical research establishments. Such a journal is in effect complementary to those mentioned above and will enable the practical geophysicist to improve his background knowledge and to follow progress in long term projects which may ultimately find application in his own work.

The Geophysical Journal incorporates the earlier Geophysical Supplement to the *Monthly Notices of the Royal Astronomical Society* and, by widening its scope to include in addition to original papers, such matters as reports of geophysical discussions, short notes and letters and book reviews, attempts to increase its circulation throughout the large body of exploration geophysicists. If it can do this it will render a considerable service, as the general standard of academic geophysical knowledge of exploration geophysicists to-day is not above criticism.

There is no limit to the range of geophysical subjects which the journal covers. Contributions to the first number come from Australia, Canada, the U.K., the U.S.A. and the U.S.S.R. and the papers cover such varied subjects as the use of hydrogen bomb explosions for seismological purposes, the application of geomagnetic measurements to studies of ionic density in the outer atmosphere, polar wandering, the theory underlying calibration of gravimeters by comparison with pendulums, and a review of the recent Toronto conference. Of more immediate practical nature is a paper on a seismic refraction survey off the north coast of Cornwall. An unusual but laudable feature at the end of the journal is a series of Russian translations of summaries of the original papers.

The journal is published quarterly, the annual subscription being £3, in U.S.A. $9. Fellows of the Royal Astronomical Society receive it free of charge.

D. T. GERMAIN-JONES.

PROGRAMS FOR AN ELECTRONIC DIGITAL COMPUTER

By M. V. Wilkes, D. J. Wheeler and S. Gill

London : Academic Books Ltd. Second Edition. Pp. xiv + 238. Price 60s.

This is the second edition of a well known book, first published in 1951. The original book was derived from a set of cyclostyled notes and made very tedious reading. The new edition has been expanded by about 70 pages and, since much of this consists of explanatory material, the revised version is somewhat more comprehensible.

Progress in the use of computing machines over the past seven years is reflected in the changed emphasis at certain points. For example, in the first edition, the location of program faults is dismissed in two pages whereas now the subject occupies a chapter of seven pages.

New departures are Chapter 3 on programming machines other than EDSAC, and Chapter 8 on automatic programming. Both of these are, perhaps inevitably, disappointing, Chapter 3 because it deals in isolation with problems which do not arise elsewhere in the book, and Chapter 8 because no actual example of an auto-code is given. A misleading statement occurs on page 64 where it is implied that the replacement of the cheap but slow magnetic drum by some other form of storage having random-access is a mere question of " technical advances in the design," would that this were so !

As with the first edition so with the new, the work is divided into three parts. The first of general import, the second a specification of the EDSAC library of sub-routines, and the third of selected detailed programs. There are few fundamental changes in the second and third parts although it is surprising that the sections on matrix operations have disappeared from part two, whereas most computing laboratories have found that their importance has increased.

The new edition has been completely re-set in type which is aesthetically more satisfying than the original " unjustified " photographic reproduction of vari-typescript and the authors have added numerous examples (with solutions) for the reader to work out. The book will be an essential for anyone who has access to the EDSAC machine and will be read with interest by users of other machines.

A. D. Booth.

FUNDAMENTAL THERMODYNAMICS FOR ENGINEERS

By M. H. Everdell

London : English Universities Press Ltd. Pp. xvi + 201. Price 25s.

This is an excellent book.

Step by step the author shows how the basic principles of thermodynamics can be developed from the premises of the first and second laws.

Diagrams are simple yet adequate and are gratifyingly close to the relevant text, and each chapter is concluded with brief, well-chosen exercises.

The arguments are clearly presented and the engineering student who follows them closely will be well equipped to tackle practical thermodynamic problems—far better equipped than his brethren to whom Entropy all too often means only something which stays constant during an isentropic process.

Particularly commendable is the inclusion of the chapter on the relationship between Entropy and Probability. The rigorous proof is not attempted but the reason employed is sufficient to ensure acceptance of the validity of the concept.

This chapter alone is sufficient reason for the book finding its way on to the bookshelf of not only the student but the practising engineer also.

The latter will find it a valuable reminder of the fundamental physical meaning of the thermodynamic functions, which he uses—often all too glibly—in solving practical problems.

R. S. Silver.

THE ELEMENTS OF CLASSICAL THERMODYNAMICS FOR ADVANCED STUDENTS OF PHYSICS

By A. B. Pippard

London : Cambridge University Press. Pp. vii + 165. Price 15s.

Thermodynamics means quite different things to the philosopher, the applied mathematician, the physicist, the physical chemist and the heat engineer. This book is written primarily for the physicist and the philosopher, it is of small direct interest to the applied mathematician and the physical chemist as it hardly ever mentions actual numbers, and even less to the engineer as neither the word " efficiency " nor " engine " occur in the index at all. It is a clear and well written account of the qualitative arguments and the differential equations of thermodynamics and the puzzling conundrums that arise when one questions such possibilities as negative temperature or the difference between the radio and visible temperature of the sun. It does in fact represent a beautiful example of the " physical thinking " which is so well taught in the Cavendish and which should always lie at the back of any quantitative numerical solution to a thermodynamic problem. The argument starts with the Zeroth law of thermodynamics which is shown to be necessary at the very beginning of the more advanced logical development of the subject but which is taken for granted without consideration by the less philosophical student. This enables temperature to be defined in terms of a perfect gas and brings in internal energy and the first law entirely phenomenologically. A discussion of reversibility leads to the second law as a generalization of what Eddington called " times arrow." The formulations of this law by Clausius, Kelvin and Carathedory are compared rather to the detriment of the

last as not being intuitively obvious nor supported by a mass of experimental evidence. It is typical of the careful approach of the author that he then proceeds to develop the consequences of the law in several alternative ways. The third law is stated in the form of the unattainability of the absolute zero. The remainder of the book deals with the application of the laws to simple systems, phase equilibrium and higher-order transitions except for a chapter of further development of thermodynamic inequalities where the valuable concept of the availability of a system in given surroundings is introduced to the physicist.

To the reviewer, the book is a most refreshing change from so many books of thermodynamics because of the interesting probing into the arguments and possible puzzling cases and it can be highly recommended for the use of the advanced students of physics for whom it is intended.

M. W. THRING.

The Institute's Journals

PRINCIPAL CONTENTS OF THE AUGUST, 1958, ISSUES

Journal of Scientific Instruments: Volume 35, No. 8

SPECIAL ARTICLE

Infra-red and microwave modulation using free carriers in semiconductors. By A. F. Gibson.

A description of the classical Drude-Zener theory of the dielectric constant and conductivity of a conductor is given, with particular reference to germanium and other semiconductors. The degree of agreement between theory and experiment is indicated. Methods whereby the conductivity of a semiconductor may be modulated and the application of these techniques to the study of the optical and microwave properties of a semiconductor are described.

ORIGINAL CONTRIBUTIONS

Magnetic deflexion of electron beams without astigmatism. By G. D. Archard and T. Mulvey.

An electron beam passing through a magnetic deflecting field is, in general, subject to astigmatism. For circular pole-pieces, this takes the form of focusing in the plane of deflexion ; for square pole-pieces, focusing perpendicular to the plane of deflexion. Deflexion free from astigmatism can be achieved by means of circular pole-pieces from which semi-circular portions have been removed. An application of this to reflexion electron microscopy is described.

Error in temperature measurement due to the interdiffusion at the hot junction of a thermocouple. By A. J. Mortlock, A.Inst.P.

Temperature measurement errors due to interdiffusion at the hot junction of a thermocouple are discussed and corresponding theoretical expressions derived. Applying these it is found, for example, that a platinum/platinum-13% rhodium thermocouple in a gradient of 10° C/cm may be in error to the extent of about 1·3° C at all temperatures within the normal operating range, following a heat treatment equivalent to 100 days at 1500°C. This is so only if the thermocouple is used in the conventional way with its arms parallel. If the same thermocouple were operated with its arms arranged in an antiparallel fashion, the error would be less.

A simple phase sensitive rectifier for use with radiation detectors. By J. C. S. Richards.

The ratio of light to dark resistance of a cadmium selenide photocell is sufficiently great for the cell to be used effectively as a light-controlled switch. Where radiation incident on a detector is chopped at a frequency of less than 20 c/s, two such photocells can be used in a very simple arrangement to make a coherent demodulator which has the advantages of a mechanical rectifier without the usual disadvantages.

A nuclear plate camera for angular distribution measurements with gaseous or solid targets over a wide range of angles. By W. M. Jones and D. G. Waters.

A nuclear plate camera for the investigation of the angular distributions of charged particles from either solid or gaseous targets is described. The instrument has been checked by comparing the angular distributions of deuterons elastically scattered from gold and xenon targets, with the Rutherford scattering law down to 8° in the forward direction.

A mass spectrometer mass marker. By J. H. Beynon, A.Inst.P., and S. Clough.

An instrument has been constructed which utilizes the galvano-magnetic effect in bismuth to measure the field strength of a mass spectrometer magnet, and hence to determine the masses of peaks as they occur when the spectrum is scanned by variation of the magnetic field strength at constant accelerating voltage. The bismuth coil is mounted between the pole-pieces of the magnet and the instrument marks on the mass spectrum a series of fifty mass calibration points at predetermined values of bismuth resistance and hence of magnetic field. Masses can be determined with the instrument to $\pm 0{\cdot}05$ mass unit in the range up to mass 200 and to an accuracy of $\pm 0{\cdot}025\%$ above this range.

An apparatus for the viscometry of organic liquids at high temperature. By W. G. Burns, B. Morris and R. W. Wilkinson.

An apparatus suitable for the measurement of the viscosity of organic liquids at temperatures of up to 400°C is described. A sealed glass capillary viscometer is used so that oxygen can be excluded and measurements made above the normal boiling point. The viscometer is immersed in a molten salt mixture contained in a welded tank and is viewed through special windows. These consist of Kodial polished glass disks sealed to Kovar cylinders. A rotation arrangement enables the viscometer to be inverted. Examples are given of its uses on known materials and on the effect of irradiation of para-terphenyl.

A critical method of focusing an optical diffractometer. By C. A. Taylor, F.Inst.P., and B. J. Thompson, Grad.Inst.P.

A simple but critical method of focusing the optical diffractometer is described. It depends on certain features in the intensity distribution near the focus in an error-free diffraction image of a circular aperture. Minor modifications to the optical diffractometer necessary to permit the application of the method are indicated.

A double γ-ray spectrometer for coincidence counting of positrons. By J. W. Weale.

A double γ-ray spectrometer has been developed as a specific method for the counting of positrons in the presence of other β- and γ-ray emitters. It has a discrimination factor about a hundred times better than a simple γ-ray spectrometer. A method of efficiency calibration including correction for the effect of positron-γ-ray coincidences is described.

The use of a manometric densitometer for molten salts. By the late L. J. B. Husband.

A manometric method of determining the density of a liquid is described. After calibration of the densitometer only remote observations need be made of a setting to a fiducial line and of the pressure of an applied gas. No confining fluid is used. This makes the densitometer particularly suitable for liquids at high temperatures. The densities of the following inorganic salts above their melting points have been found : sodium nitrite, potassium thiocyanate and potassium chlorate.

The preparation of powder specimens from active and toxic metals for use in conventional X-ray diffraction studies. By A. Moore, A.Inst.P., D. B. Wright, and A. J. Martin.

An argon dry box and an associated procedure is described for the preparation of specimens for use in Debye-Scherrer powder cameras at high and low temperatures. Special features allow filings to be annealed at > 1200°C, and quenched, if necessary, in vacuo : there is no need for filings to be sealed in a container for this purpose. Filings can be sealed in silica quills ($\sim 0{\cdot}025$ in. o. diameter and wall thickness $\sim 0{\cdot}005$ in.) for use as specimen, by a small electrical furnace.

The dry box is designed to enable an operator to be fully protected and to have fine control over the specimen at all stages of its preparation.

Photoelectric indicator for precision setting in co-ordinate measurements. By E. Djurle and G. Gran.

Precision measurements of co-ordinates on photographic plates are tedious and tiring with ordinary microscopes with a visual setting. The present electronic indicator presents the intensity in the line or point to be measured as mirror images on an oscilloscope and uses the traces as coincidence marks. Measurements can be made in two co-ordinate directions with a standard deviation of $0{\cdot}3\mu$ or better for the setting on a line or point.

British Journal of Applied Physics: Volume 9, No. 8

SPECIAL ARTICLE

Atmospheric pollution and the soiling of textile materials. By W. H. Rees, F.Inst.P.

The paper opens with a discussion of the factors which influence the soiling of textile materials by airborne dirt and of a method for measuring and expressing the extent of soiling of textile materials. An account is then given, with experimental data, of the soiling of textile fabrics by exposure to moving air, by thermal precipitation and by electrostatic attraction of airborne particles, and of the effect of fabric wettability on the appearance of a cotton fabric soiled by exposure to a damp polluted atmosphere. Finally, the paper introduces the " murk " unit of air dirtiness and deals briefly with the measurement of atmospheric murk values. Typical data for a residential district are given showing differences in the magnitude and diurnal variation of air dirtiness in summer and autumn.

CONFERENCE REPORT

Summarized proceedings of a conference on electron microscopy—Bangor, September, 1957

The Annual Conference of the Electron Microscopy Group of The Institute of Physics was held in the Department of Botany, University College of North Wales, Bangor, from September 10 to 12, 1957. The papers presented, and discussion on them, are summarized in this report.

ORIGINAL CONTRIBUTIONS

The ratio of characteristic to white X-radiation from a copper target. By E. G. Bendit.

The ratio (k) of the total Kα radiation to the total white radiation emitted by copper target X-ray tubes has been estimated by isolating the contribution of wavelengths near $\lambda K\alpha$ with balanced nickel and iron filters. The total radiations leaving the tube have been inferred from the counting rates of a Geiger counter exposed to the direct beam from the X-ray tube (suitably attenuated by a pinhole system). Corrections for transmission of the air path and quantum efficiency of the Geiger counter as functions of wavelength were applied to an assumed spectral distribution for the white radiation. The assumed spectral distribution was selected on the basis of a literature survey of investigations on continuous spectra, a brief outline of which is given. It is found that at 35 kVp, $k = 2{\cdot}2$, a result which lies between those of Arndt and Riley, who found $k = 5{\cdot}4$, and of Parrish and Kohler, from whose curves a value of $k = 0{\cdot}35$ is deduced. A measure of reconciliation between these results is achieved if various corrections and different experimental conditions are taken into consideration. Curves show the variation of k over the target area, with take-off angle, and with voltage ; the form of the voltage variation agrees with the results of Guinier.

The ageing of vacuum standard lamps on a.c. and d.c. By W. Barnett, R. G. Berry, and J. S. Preston, F.Inst.P.

A comparison is made of the rates of fall of luminous intensity and current, at constant voltage and colour temperature 2390°K approximately, of 100V 30W vacuum photometric standard lamps, on a.c. and d.c. supplies. The rate for intensity is considerably higher on d.c. than on a.c., while the rate for current is lower. These specific effects of d.c. operation can be accounted for simply by changes in filament emissivity. There is no necessity to postulate a migration of tungsten along the surface of the filament, as in the author's previous work on gasfilled lamps. The effects are shown to be almost fully reversible, after many hours of burning, by suitable application of reversed d.c., and a.c., supplies. As for gasfilled lamps, the usefully smaller rate of depreciation characteristic of a.c. operation may be fully retained on d.c. by reversal of polarity at regular convenient intervals, so that the use of a.c. becomes legitimate for the normal preliminary ageing tests.

The dependence of stress distribution on elastic constants. By Margery Clutterbuck, A.Inst.P.

Experimental methods in stress analysis are becoming increasingly important in the design of engineering structures, particularly in the aircraft and associated industries. In this paper, the effect of the elastic constants on certain stress distributions is investigated using the photoelastic technique. Similarity in stress distributions is obtained by suitable adjustment of the loads with respect to the Young's moduli of the materials from which the models are made, but no such adjustment is possible to compensate for the differences in their Poisson's ratios. The error introduced by this effect is considered by reference to problems of a particular type, from which some general conclusions are drawn.

Pulse-annealing technique for metals and alloys. By P. Wright, F.Inst.P., and K. Thomas, Grad.Inst.P.

An account is given of some improvements in the technique of pulse-annealing. Procedures for sharpening up the pulsing and quenching processes, and for accurately controlling the annealing temperature, are described. Some experimental results on Cu_3Au are given to illustrate the special uses of the pulse-annealing method.

A constant liquid flow device. By G. H. Laycock, A.Inst.P.

The theoretical design is given for a device, which passes a constant liquid-flow irrespective of wide viscosity variations, consisting of an orifice in series with capillary restrictor. A device based on this design is described and experimental results showing that a constant flow is obtained are quoted. An alternative means of rendering the flow automatically independent of viscosity is suggested.

The effect of gettering on the reflectivity of aluminium films. By L. Holland, F.Inst.P.

Aluminium films evaporated on glass from a single vapour source are more optically absorbing at high angles of vapour incidence if the films are slowly deposited or prepared in a poor vacuum. The rise in the optical absorption with vapour incidence angle is attributed to the degree of gas contamination of the growing film increasing as the deposition becomes more oblique. Such an effect could arise from a greater ratio of the number of gas molecules to vapour atoms combining at the receiver in regions of low vapour intensity. The reflectivities of aluminium films prepared at different gas pressures and rates of deposition show qualitative agreement with the hypothesis when plotted as a function of vapour incidence angle. The simple theory advanced is not applicable at gas pressures above 1μ mercury because the vapour atoms are scattered by gas molecules before striking the receiver.

GLOUCESTER TECHNICAL COLLEGE
DEPARTMENT OF SCIENCE

A LECTURER IN PHYSICS, able to teach up to B.Sc. General and Grad.Inst.P. standard, is required from September 1, 1958, or as soon as possible thereafter. The person appointed will be responsible, under the direction of the head of department, for the work in physics. The salary will be in accordance with the Burnham scale for Lecturers, viz. £1,200 × £30 – £1,350. Application forms and further particulars may be obtained from the Principal, Technical College, Brunswick Road, Gloucester, to whom completed forms should be returned as soon as possible.

AUSTRALIA — UNIVERSITY OF SYDNEY

RESEARCH STUDENTSHIPS/FELLOWSHIPS IN PHYSICS

Applications are invited for Research Studentships (£850 – £1,050 Australian per annum), Research Fellowships (£1,100 – £1,800 Australian per annum) in the School of Physics. The category and starting salary of successful applicants will be judged according to qualifications and experience. Fares to and from Australia not exceeding a total of £200 (Australian) may be paid. The awards will normally be made for a period of two years, after which the tenure may be renewed for a further period. Pre-doctoral candidates will normally be awarded research studentships and will be expected to pass the Physics IV examination at honours B.Sc. level before proceeding to work for the Ph.D. degree. Study for this examination may take up part or all of the first year in Sydney. Theoretical research into problems of nuclear, atomic and solid-state physics is being actively pursued in the school of physics under the direction of Professor H. Messel, and Drs. S. T. Butler, J. M. Blatt and M. R. Schafroth, and a large high-speed digital computer is available. Research Fellows who would be interested in working on theoretical aspects of nuclear reactions are particularly required. Experimental work in the school of physics is concerned with a variety of aspects of cosmic ray physics. Nuclear research emulsions, cloud chambers and counters are used in the experiments at present being carried out.

Applications giving names of three referees should be forwarded to reach the undersigned* not later than November 15, 1958. Overseas candidates are also requested to forward a copy of their application to the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1, by the same date.

* M. A. Telfer, Registrar, University of Sydney, Sydney, New South Wales, Australia.

MID-ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART
MARKET ROAD, CHELMSFORD

LECTURER IN PHYSICS required from January 1, 1959, or earlier if possible. Candidates should have a good honours degree or equivalent together with teaching, research, or industrial experience, and be able to offer specialized knowledge of a branch of applied physics.

Salary : £1,200 × £30 – £1,350 per annum.

Details and application forms (stamped addressed foolscap envelope) from the clerk to the Governors at the college to whom completed forms should be returned as soon as possible.

PHYSICIST

Iraq Petroleum Co. Ltd., requires a physicist for work in its Reservoir Engineering Laboratory in London on the analysis of reservoir performance with the aid of electric analogue computors.

Applicants should have a good honours degree and some experience of electronics.

The selected candidate will be required to spend a short initial period in the Middle East to acquaint himself with the background of the work he will be doing in London. Age range 25 – 30. Salary will be assessed according to age and experience. There is a pension scheme and a luncheon club in the building.

Write in full to Staff Manager :

Iraq Petroleum Co. Ltd.,
214 Oxford Street, London, W.1.

LONDON COUNTY COUNCIL

PHYSICIST
(SENIOR SCIENTIFIC OFFICER)

required by London County Council in the scientific branch at County Hall for research work on properties of materials and in the field of health physics. Good honours degree in physics and general physical experience required, with knowledge of radiochemical equipment. Salary within scale £1,037 10s. – £1,305 according to qualifications and experience. Permanent and pensionable. Good promotion prospects. Apply to Medical Officer of Health (PH/D. 1/A), County Hall, London, S.E.1, by September 1. (1432).

MIDDLESEX COUNTY COUNCIL
EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY
WOODLANDS AVENUE, ACTON, W.3

Applications are invited for an additional post of SENIOR LECTURER IN PHYSICS. Applicants should be well qualified in physics and should be prepared to teach to the level of the Diploma in Technology in Applied Physics. Research facilities and the development of project work for fourth-year diploma in technology students available. An interest in some branch of solid state physics may prove an advantage. Applicants are expected to take up the post on January 1, 1959.

Salary in accordance with the Burnham (Technical) Report 1956.

Apply (stamped addressed envelope) immediately to the principal.

C. E. Gurr, M.Sc., Ph.D.,
Clerk to the Governing Body.

COVENTRY TECHNICAL COLLEGE
ELECTRICAL ENGINEERING AND PHYSICS DEPARTMENT

Applications invited for full-time post of GRADE B ASSISTANT to teach physics in National Certificate, sandwich and degree courses to full-time, part-time day and evening students.

Burnham Technical Scale Salary (men) £650 × £25 – £1,025. Application forms and further particulars from Director of Education, Council Offices, Coventry.

AUSTRALIA — UNIVERSITY OF SYDNEY

LECTURESHIPS IN PHYSICS

Applications are invited for two positions of lecturer in physics. One lectureship will be filled by an experimental physicist and preference will be given to candidates working in the field of cosmic radiation. The other lectureship will be filled by a theoretical physicist.

The salary for a lecturer is within the range £A1,500 × £90 – £2,100 per annum, plus cost of living adjustment, and will be subject to deductions under the State Superannuation act. The commencing salary will be fixed according to the qualifications and experience of the successful applicant.

Under the staff members' housing scheme in cases approved by the University and its bankers, married men may be assisted by loans to purchase a house.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. The closing date for the receipt of applications, in Australia and London, is August 29, 1958.

COLLEGE OF TECHNOLOGY, BIRMINGHAM

(Designated College of Advanced Technology)

Principal : P. F. R. Venables, Ph.D., B.Sc., F.R.I.C.

RESEARCH FELLOWSHIPS

As part of the expansion of the work of the college since its designation as a College of Advanced Technology, the governors have established Research Fellowships in the following departments :

Chemistry
Metallurgy
Electrical Engineering
Physics
Industrial Administration

Candidates must either have shown exceptional promise in research in science or technology, or in industrial experience relevant to the proposed subject for research. They should possess a good first degree, and a higher degree gained as the result of research work ; or possess a College Associateship or Diploma in Technology or appropriate professional qualification followed by exceptionally valuable and interesting industrial experience, or appropriate research work in industry, research associations or government establishments. Candidates should submit their own research proposals for consideration.

The salary scale is equivalent to that laid down by the Burnham Technical Report for Grade " B " Teachers, i.e. £650 × £25 – £1,025 plus graduate and training allowances. Further details can be given on the basis of the applicant's biographical data. However, as an indication, it may be noted that an applicant with a good honours degree or a Ph.D., gained as a result of five years' approved full-time study, would have a starting salary of £850.

The appointment, normally tenable for three but not more than four years, will be made as from September 1, 1958, or as soon as possible thereafter.

Further particulars and forms of application from the Registrar, College of Technology, Gosta Green, Birmingham, 4, on receipt of stamped addressed foolscap envelope. Applications to be received within 18 days of this advertisement. Please quote " V."

K. R. Pilling,
Clerk to the Governing Body.

THE COLLEGE OF AERONAUTICS

LECTURER in aircraft materials required to teach at postgraduate level in one of the following fields : metals technology ; non-metallic materials ; solid mechanics. Candidates will be expected to have a degree in a relevant subject, such as metallurgy or physics, and both industrial and teaching experience would be advantageous. Research activities are encouraged, and opportunity exists for supervision of student researches. Salary according to qualifications and experience, in scale £900 × £50 to £1,350 × £75 – £1,650 per annum, with superannuation under F.S.S.U., and family allowance. Applications giving full details of qualification, etc., and quoting the names of three referees, to the Recorder, The College of Aeronautics, Cranfield, Bletchley, Bucks. Further particulars available.

COMMONWEALTH OF AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION
DIVISION OF FOOD PRESERVATION AND TRANSPORT

APPOINTMENT OF PHYSICIST

Applications are invited for appointment to a position of physicist with the organization's division of food preservation and transport located at Homebush, New South Wales. The appointee will be required to participate in investigations of the relation between the vapour pressure and the water content of biological materials, and in the development and assessment of objective methods for measuring differences in colour between samples of particular foodstuffs. From time to time he will be asked to undertake short term investigations of other physical or instrumentation problems arising in the Division's laboratories. Applicants should possess a university degree in science, applied science, or engineering, or a technical college diploma, or equivalent qualifications. Some practical experience in instrumentation, electronics, or vacuum techniques would be an advantage. Dependent upon qualifications and experience, commencing salary will be determined within the salary ranges of Experimental Officer, Grade I, £A996 – £A1,416 p.a., or Experimental Officer Grade II, £A1,416 – £A1,686 p.a. Salary for a female appointee would be £A170 p.a. less than the corresponding male rates. The appointment will be conditional upon a satisfactory medical examination. Confirmation of appointment carries with it Commonwealth Superannuation Fund or Commonwealth Provident Account privileges.

Fares to Australia, including those of wife and dependent family, will be provided by the Organization. Details may be discussed with the undersigned. Applications quoting appointment number 300/207 and stating full name, place, date and year of birth, nationality, marital state, present employment, particulars of qualifications and experience, and of war service if any, together with the names of not more than four persons acquainted with the applicant's academic and professional standing, should reach the undersigned, from whom further particulars may be obtained, by September 1, 1958.

E. J. Drake,
Chief Scientific Liaison Officer,
Australian Scientific Liaison Office,
Africa House, Kingsway,
London, W.C.2.

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

MINISTRY OF SUPPLY RESEARCH AND DEVELOPMENT ESTABLISHMENTS, mainly in southern half of England, require (*a*) senior scientific officers (minimum age 26) and (*b*) scientific officers for work in physics, electronics, electrical or mechanical engineering, applied mathematics, aerodynamics, chemistry or metallurgy. First or second class honours degree or equivalent required and for S.S.O. at least three years' postgraduate experience. Starting salary in range (*a*) £1,130–£1,330, (*b*) £595–£1,050 (male, in provinces). Rates for women reaching equality in 1961. Superannuation under F.S.S.U. Opportunity for those under 32 to compete for established posts. Candidates should indicate fields of work in which interested. At National Gas Turbine Establishment, Pyestock, Hants., houses available for letting to married staff, and opportunities for new graduates to have workshop training. Forms from M.L.N.S. Technical and Scientific Register (K), 26 King Street, London, S.W.1 (quote A.300/8A).

Guided weapons. PHYSICISTS and ENGINEERS required by Ministry of Supply at Royal Aircraft Establishment, Armament Research and Development Establishment and Royal Radar Establishment, for research on guided weapons (including ballistic missile) and supervision of development in industry. First or second class honours degree or equivalent required for Scientific Officer (£595–£1,050) and three years' postgraduate experience in addition for senior scientific officer (£1,130–£1,330). Women's rates the same by 1961. Superannuation under F.S.S.U. Opportunity for those under 32 to compete for established posts. Forms from M.L.N.S. Technical and Scientific Register (K), 26 King Street, London, S.W.1. (Quote A.291/8A). Closing date, September 24, 1958.

BICC

PHYSICIST or ELECTRICAL ENGINEER, graduate preferably of honours degree standard required for the Shepherds Bush research laboratories of British Insulated Callender's Cables Ltd. The work involves research and development on dielectrics and capacitors. Previous experience in this field would be desirable but is not essential. Five-day week; pension fund. Applications giving details of age, qualifications and experience to be made to Personnel Officer, B.I.C.C. Ltd., 38 Wood Lane, London, W.12.

TECHNICAL LIBRARY AND INFORMATION BUREAU requires a male assistant, preferably 21-35 years with knowledge of chemistry and physics, French and German. Some acquaintance with biology useful. Good prospects. Five-day week. Staff restaurant and Pension Scheme. Please apply to the Personnel Officer, Griffin and George Ltd., Ealing Road, Alperton, Middlesex.

TECHNICAL ASSISTANT required to control and service the high voltage accelerator which is being installed at Reading for work on radiation damage. Physics or electrical engineering to pass degree standard or a Higher National Certificate in Applied Physics or Engineering is desirable. Commencing salary in the range £450–£650 according to age and qualifications. Applications to be sent to the Professor of Physics, The University, Reading, as soon as possible.

UNIVERSITY OF READING
DEPARTMENT OF PHYSICS

RESEARCH STUDENTSHIP IN THEORETICAL PHYSICS

Applications are invited for a research studentship in theoretical solid state physics. The award, which is for three years, will provide training in research in theoretical physics leading to the Ph.D. degree, and will be for investigations in the general field of imperfections in crystalline solids.
Salary and fees will be provided at the same level as D.S.I.R. postgraduate studentships, but previous postgraduate experience will be taken into account. Applications giving qualifications and the names of two referees to be sent to the Professor of Physics, The University, Reading, by September 20, 1958, from whom further particulars may be obtained.

GRADUATE PHYSICIST required at Dunlop Research Centre for research on dependence of physical properties of natural and synthetic rubbers upon their molecular structures. Excellent laboratory facilities and modern techniques available for these studies. Usual five-day week, pension scheme, etc. Please write in confidence, giving age, experience (if any) and commencing salary expected, to Personnel Manager (Reference J.M.154), Fort Dunlop, Erdington, Birmingham, 24.

CAVENDISH LABORATORY, CAMBRIDGE

SENIOR RESEARCH ASSISTANT required for experimental research on the aberrations of electron lenses. A knowledge of electron optics and vacuum physics would be an advantage, but applicants who have experience of instrument design, in particular fine mechanisms, will also be considered. In general, post-doctoral candidates would be preferred, but an outstanding candidate without this qualification who wishes to work for a higher degree would be given the usual facilities. Salary in the range £750-£1,200 according to age and qualifications, together with membership of F.S.S.U. where appropriate.
Applications with the names of two referees should be submitted to the Secretary of the Department of Physics, Cavendish Laboratory, Free School Lane, Cambridge, by September 30, 1958.

GOVERNMENT OF HONG KONG

PHYSICIST required for Radiological Department to collaborate with radiologists on treatment techniques, supervise radiological workshop, assist in maintenance and development of equipment, maintain radiation protection services and instruct students. Appointment on contract for three years but shorter period could be arranged if necessary. Emoluments include basic salary on scale from £1,035 to £1,897½ a year ; expatriation pay from £210 to £281¼ a year; and variable cost of living allowance, which on minimum of salary scale is £41 a year for single man; £175 a year for married man with no children ; and £310 a year for married man with dependent children, boys under 18 and girls under 21 years. Commencing salary depends on experience. On satisfactory completion of service a gratuity is payable from £37 10s. 0d. to £62 10s. 0d. for each completed period of three months service. Arrangements could be made for preservation of superannuation rights of candidate from National Health Service.

Free passages for officer, wife and up to three children under 18. Pending quarters becoming available, hotel or hostel accommodation provided. Maximum charge for quarters, hotel or hostel accommodation one-seventh of basic salary. Income tax at local rates. Climate favourable. Educational facilities available.

Candidates must possess Honours B.Sc. degree in Physics and have had at least five post-qualification experience as hospital physicist.

Application forms from Director of Recruitment, Colonial Office, London, S.W.1 (quoting BCD117/51/013).

PHYSICIST

required as Head of the Physics Department of the Brown-Firth Research Laboratories. Qualifications Ph.D. or 1st or 2nd class Honours Physics degree, with some research experience. Age preferably around 30 years. The main works are in Sheffield and the company is engaged in the manufacture of high-grade alloy steels; stainless and heat resisting steels; large steel forgings, such as rotor shafts and hardened steel rolls. The research laboratories are quite close to the works. The main duties will be the direction and supervision of the work of the Physics Department, which generally consists of the application of physics to the improvement of production methods. However, much of the work is fundamental in character: heat flow calculations; studies of residual stresses in forgings and the diffusion of hydrogen are examples of the type of problem encountered. There is also a fair amount of Physical Metallurgy, particularly on the transformations in steel. The position is an important one and carries a commensurate salary. Applications should initially be in writing stating age and full details of qualifications and experience and should be addressed to : The Personnel Manager, Thos. Firth and John Brown Ltd., Employment Department, Atlas Works, Sheffield 4.

NORTHAMPTON COLLEGE OF ADVANCED TECHNOLOGY, LONDON

DEPARTMENT OF APPLIED PHYSICS,
ST. JOHN STREET, E.C.1.

RESEARCH ASSISTANT. Applications are invited for a research assistant for work on the establishment of a scale of subjective brightness which is of importance in illuminating engineering. The work will be concerned with photometry and physiological optics. The applicant should have an honours degree in physics or equivalent qualifications. The work should lead to a higher degree.

A limited amount of demonstrating work will be required but this will not amount to more than six hours per week. The remuneration including payment for teaching assistance amounts to £400-£500 per annum.

Applications should be sent to the Head of the Department of Applied Physics, as soon as possible, from whom further particulars can be obtained.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH. Principal Scientific Officer. Pensionable post for ENGINEER or PHYSICIST at least 31 on January 1, 1958, at Mechanical Engineering Research Laboratory, East Kilbride, Glasgow, to lead team carrying out research on heat transfer in a new laboratory with exceptional facilities. Qualifications normally first or second class honours degree in an appropriate subject or high professional attainment. Sound knowledge of basic principles and experimental techniques of heat transfer and fluid mechanics necessary. Industrial experience desirable. Salary scale (men) £1,370–£1,950. Good housing prospects. Write Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, for application form quoting No. S4881/58. Closing date September 23, 1958.

PLESSEY NUCLEONICS LTD. NORTHAMPTON

JUNIOR PHYSICISTS

Applications are invited for a number of posts in the development laboratory of this Company. Successful candidates would work as members of a team engaged in the application of the techniques of nuclear physics to a wide range of problems. A degree in physics is necessary and one or two years' experience of research or development work in similar fields would be an advantage. The company offers attractive salaries and working conditions and the positions will provide ample scope for advancement in this rapidly expanding industry. Applications to The Personnel Manager, Plessey Nucleonics Ltd., Weedon Road, Northampton.

LABORATORY TECHNICIAN. A laboratory technician is required to work in a team engaged on the development of radiation detectors of all types for the nuclear energy industry. Experience in this field would be an advantage but is not essential. A knowledge of light engineering and general physics laboratory practice including high vacuum techniques is desirable. The position will involve the construction and evaluation of new types of detector and the development of new techniques of construction. The minimum qualification for the above post is H.N.C., but a more junior post is also available. Applications should be made in writing to the Personnel Department, Plessey Nucleonics Ltd., Weedon Road, Northampton.